Statement of the problem:

THE AREAL DENSITY in magnetic recording has reached 20 Gbit/in^2 in products and is increasing at a rate of ~100% per year. Data rates are approaching Gbit/s levels and are increasing at a rate of 30-40% per year. An earlier perceived density limit of 40 Gbit/in^2 [1] has been surpassed in laboratory demonstrations [2] and feasible densities of 100 – 500 Gbit/in^2 are targeted in perpendicular recording [3]. Such projections are based upon scaling assumptions and future technological advancements in areas of write and read heads, media, channel electronics, tribological coatings, head-disk-interface and narrow track servo capability.

An area of particular importance is media noise suppression, which involves the reduction and scaling of the media grain size, control of the magnetic grain isolation and uniformity and control of the crystallographic texturing. Achieving low noise media by scaling to smaller grain size, however, is limited by thermal instabilities, which may render today's commonly used Co-alloy based recording media unsuitable for archival data storage. This should be the case for grain diameters below about 8-10 nm [4]. Smaller, stable grains can be obtained from magnetically harder materials, prominent candidates of which are tetragonal $L1_0$ phased FePt or CoPt compounds, or artificially layered materials, e.g. Co/Pt or Co/Pd multilayers. Other candidates are rare earth transition metal compounds, such as Co_5Sm or $Nd_2Fe_{14}B$. However, these materials may be difficult to maintain chemically stable in hard disk media, where minimal overcoat thickness is mandatory.

A common dilemma with high anisotropy materials is large coercivity, which can reach values of the order of 50,000 Oe [5], far exceeding the write field capability of today's recording heads. To alleviate this problem, vertical recording and thermally assisted recording schemes have been proposed.

Lithographically patterned media (bit-patterning) could postpone the arrival of thermal instabilities by combing several hundred media grains into one single magnetic island, which does not require large coercivities. For a comprehensive review of this field see ref.[6]. The achievable density in this approach is limited by lithography to perhaps about 1 Tbit/in^2 [6].

In order to push beyond this density limit set by lithography, self-assembled nanoparticle arrays have been proposed [7,8]. Such self assembled, ordered and uniform nano-magnet arrays provide conceivable solutions to any of the proposed future recording schemes (conventional granular media, perpendicular media, thermally assisted recording, patterned media). A representative 6 nm FePt nanoparticle arrays with typical bit dimensions and achievable areal densities is shown in Fig.1 below.

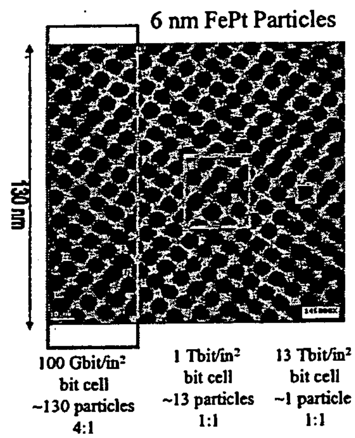

Fig 1: 6 nm FePt self organized nano-magnet array from ref [8].

This specific array has a surface area of about 130 x 130 nm^2 and comprises about 260 particles per layer. The corresponding particle density per surface area is ~ 10 Tparticles/in^2. In a future single particle per bit patterned recording scheme, this could lead to respective areal bit densities of 10 Tbit/in^2. There are many technological challenges. One of the main problems, which is solved by the present invention, is large scale ordering. In [7,8] it is shown that regular FePt arrays order on a lateral structural coherence length, i.e. the distance over which uniform, ordered arrays as shown above can be formed, is of order ξ=100-1000 nm. This is far less than required in magnetic recording disks. It is thus proposed to combine large scale 'lithographic' patterning on a length scale compatible with standard optical or electron lithography with small scale 'natural' patterning using self-assembly of nanoparticles.

Detailed Description of Invention:

The invention involves a two step fabrication process. The first step requires pre-patterning in order to generate a long length scale topographic "locking pattern" on a magnetic recording disk substrate (e.g. glass ceramic or Al-Mg). In the second step this locking pattern is filled with magnetic nano-particles exhibiting short-range order.

The creation of the locking pattern is possible using various methods. For instance, standard laser beam, electron beam, deep UV lithography, or nano-imprinting can be used to generate a topographic pattern on a substrate coated with a photoresist. After clearing the resist from the exposed areas, a topographic pattern with typical dimensions of sub-micron down to 100 nm is produced by reactive ion etching (RIE). Examples of useful patterns: a square pit for a set of one or more bits, or a groove for a set of one or more tracks, or islands in certain locations to create a coarse grid to stabilize the fine grid formed by the nano-particles. The pit depth ranges between 5-20 nm deep depending on the size of particles to be used in the subsequent processing step. Alternatively, a topographic pattern can be nano-imprinted directly into a Sol-Gel-type coating (for instance, a solution of TEOS, water, and HNO_3), leaving the desired pattern after drying. This process is comparable to the process developed for PAMR at Research West / RMO. A third option is to create a flat, chemically activated surface, consisting of two types of chemical substances, spatially separated according to the desired pattern. One type attracts and the other repels the nano-particles used in the second processing step. These types of chemically active, patterned monolayers can be prepared by a number of well-known techniques.

In the second step the disks are "planarized" using chemically synthesized iron-platinum nano-particles, which are self-assembled into the topographic pit pattern following published recipes [7,8]. The lithographically generated pit pattern acts as a locking pattern on the self-assembly-coherence length scale ξ of FePt nano-particles. In addition, by chemically activating either the high or the low-lying parts of the topographic pattern during or after the pattern generation, it is possible to manipulate the areas, which the nano-particles will self-assemble in.

Figure 2 (a-d) shows the basic concept of this invention (see attached)

Literature

1. S. H. Charap, Pu-Ling Lu, Yanjun He, "Thermal stability of recorded information at high densities" IEEE Trans. Magn., Vol. 33, 978 (1997).
2. Densities in the range 36-63 Gbit/in2 have been demonstrated by Hitachi, Read-Rite, Fujitsu, Seagate and IBM.
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4. D. Weller, A. Moser, L. Folks, M.E. Best, W. Lee, M.F. Toney, J.-U. Thiele, and M.F. Doerner, "High Ku Materials Approach to 100 Gbit/, IEEE Trans. Magn. 36, 10 (2000).
5. Y. Ide, T. Goto, K. Kikuchi, K. Watanabe, J. Onagawa, H. Yoshida, and J. M. Cadogan, in^2 "Ultrahigh coercive force in epitaxial FePt(001) films" J. Magn. Magn. Mater., 245, 177 (1998).
6. G. Hughes, "Patterned Media" in *Physics of Magnetic Recording*, chapter 7, ed. Plumer, van Ek, Weller, Springer (2001)
7. S. Sun, C.B. Murray, D. Weller, L. Folks and A. Moser, Science 287, 289 (2000)
8. S. Sun, D. Weller and C.B. Murray, "Self-Assembled Magnetic Nanoparticle Arrays" in *Physics of Magnetic Recording*, chapter 9, ed. Plumer, van Ek, Weller, Springer (2001)

Date | Notes

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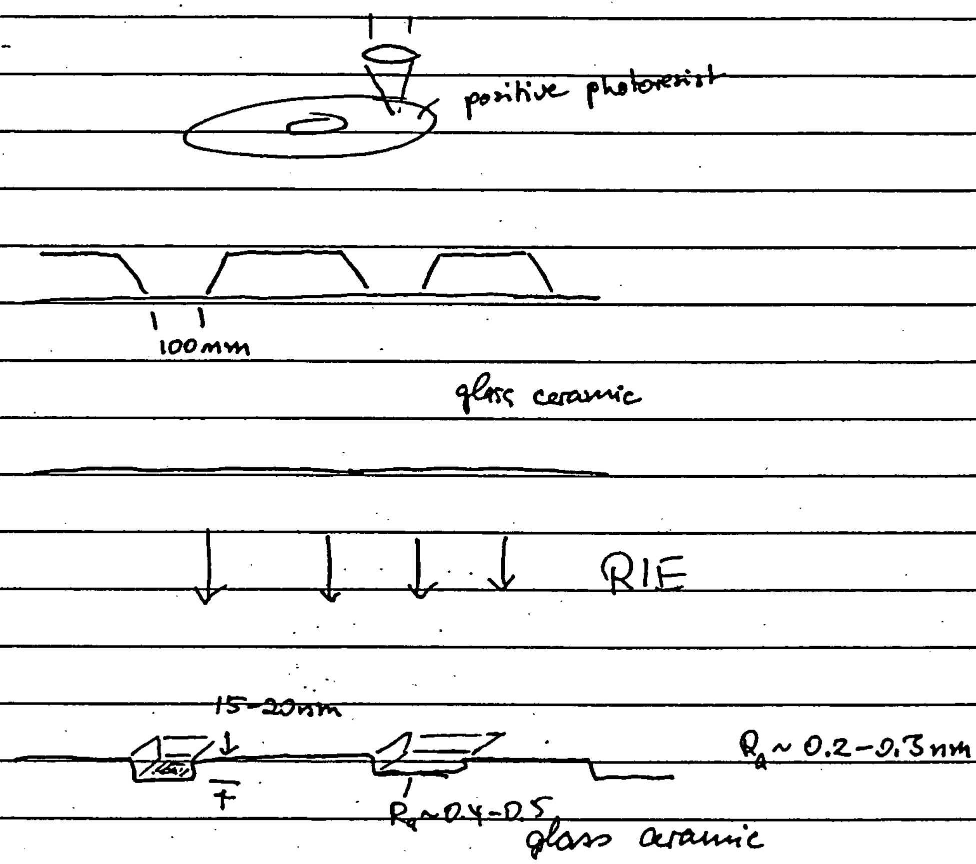
Laser Beam Deep UV 257 nm Recorder

Format Pattern Writer



(Si wafers, . . .)

- Magnetic Planarization using FePt nanoparticles (S. Sun et al., Science 287, 1989-1992, 2000)

- Generate locking pattern (topographic pattern) on the coherence length scale of the chemical ordering of FePt etc. This could also be used to texture/orient the magnetic particles

Seagate

Business Diary

Date | Notes

Deposition of FePt particles can occur __before__ removing resist, which gives chemical selectivity

- Use "locking pattern" at the same time as servo pattern

f_0

f_1 embedded servo scheme

f_0